Design and Analysis of Integrated PIFA for Wireless Applications

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Abstract - A Compact low profile Planar Inverted F-Antenna based on self-affinity is proposed with a wide frequency band for WLAN, HiperLAN & WiMAX applications. The multiband performance is realized by the integration of L-shaped slots in the radiating patch and introducing an air gap between radiating element and dielectric medium. The optimized size for the proposed structure is 35.9mm x 58.94mm x 3.45mm. This antenna achieved almost unidirectional radiation pattern. From the electrical characteristics of designed antenna, it is clear that antenna resonates at 1.20GHz, 2.82GHz, 3.58GHz, 4.02GHz and 6.68GHz with impedance bandwidths 90MHz, 60MHz, 50MHz, 260MHz and 190MHz respectively.

Keywords – *PIFA, Slot Antenna, Fractals, Air gap, Multiband and Efficiency.*

I. INTRODUCTION

Wireless communication is a boon to mankind that gave hype for the transmission of information to a very large extent in distant areas. Wireless communication has enhanced fast, secure and high data transmission rates to the consumers. There are different kinds of wireless communication technologies like Infrared, Broadcast Radio, Microwave Radio and Satellite communication. Wireless communications gratis from the repression of traditional wired network.

Antenna plays a very important role in the wireless communication. Antennas act like transducers to convert the electrical energy to electromagnetic waves. The electromagnetic waves are transferred from the sender to the receiver using antennas at both ends. Communication to very large distance can be achieved either by using repeaters or by the use of satellite communication. Today wireless communication is entirely dependent on antennas. The antennas are used simply to radiate electromagnetic energy in an omnidirectional or finally in some systems for point-to-point communication purpose in which increased gain and reduced wave interference are required.

A multiband antenna is an antenna that is designed to operate in multiple bands of frequencies. Multiband is does not require lot of space and is simple to construct and is of low cost.The Inverted F Antenna (IFA) typically consists of a rectangular planar element located above a ground plane, a short circuiting plate or pin, and a feeding mechanism for the planar element. The main advantages of PIFA are it can be hiding into the housing of the mobile when comparable to whip/rod/helix antennas; it exhibits moderate to high gain in both vertical and horizontal states of polarization.

There are several methods to develop multibands, which are used for various applications like wireless, satellite, long distance data transmission and telemedicine applications etc. 5G communication technology is focusing on to generate multiple bands at 6GHz, 10GHz, 15GHz, 28GHz and 38GHz for high data transmission rate upto 10Gbps. M K Ishfaq, T A Rahman, H T Chattha, M U Rehman proposed a design suitable for 5G applications, by using invered L-shaped parasitic element, a rectangular parasitic shaped element and a split ring resonator (SRR) is etched in the patch of PIFA. The designed antenna covers 5-7GHz, 9-10.8GHz and14-15GHz [1]. To alleviate the drawbacks encountered when wire antennas are used for mobile communications, low profile antennas such as planar inverted F-antennas [2-5] and microstrip antennas [6-8] due to their compactness and robustness.

In this paper, Planar Inverted F-Antenna is developed for multiband characteristics by integrating L-shaped slots in the radiating patch and patch is placed at some height to the substrate. The radiating patch considered with thickness of 0.25mm. Section 2 describes about the literature survey for this work. Section 3 explains design methodology of proposed antenna and it's parametric. Section 4 gives results and its discussion. Section 5 notes conclusion. Section 6 about acknowledgement and finally section 7 mentions references.

II.LITERATURE SURVEY

Mustapha El Halaoui, Abdelmoumen Kaabal, Hassan Asselman, Saida Ahyoud and Adel Asselman proposed a Planar Inverted F Antenna for the applications of quadband, which covers low frequency microwave bands by integrating four slots in the radiating patch [9].

Dual band PIFA developed for the applications of GSM900 & DCS1800 and also to reduce the size, U-shaped slots and folded structure implemented in this article [10].

For example, A Planar Square Multiband Frequency Reconfigurable Microstrip Fed Antenna With Quadratic Koch-Island Fractal Slot was designed in [11] using 16 pin diodes , 15bands obtained to cover the low frequency range over 1-6GHz.

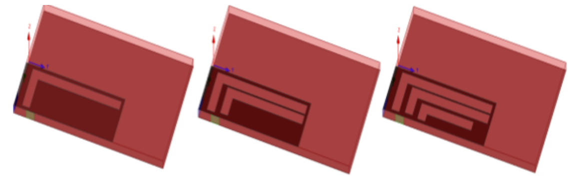
In general, fractal antennas are developed for the multiband applications from several articles. Just by modifying the planar Inverted F Antenna with Quadrate rectangular fractal, the characteristics were modified to multiple resonances with omnidirectional radiation patterns [12].

V.Arun, Md.Abdul Rawoof, A.V.Paramkusam proposed a new dualband PIFA for phone transceiver system by etching three slots in the patch element at 2.4GHz and 3.7GHz with good input impedance matching [13].

III.DESIGN METHODOLOGY

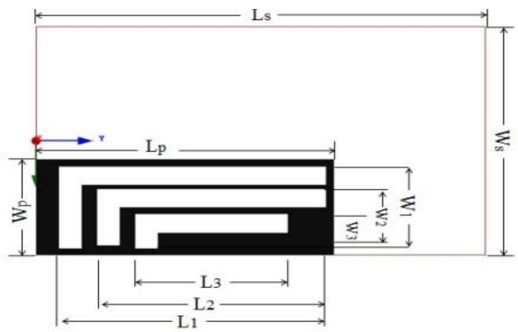
Mobile and wireless communications systems are extremely popular. Wireless devices for personal applications are portable, so that they must be smaller in size and light weight. An antenna with low profile is one of the miniaturized techniques applied in wireless devices. In order to achieve good impedance matching, a shorting can be introduced vertical to the radiating element. So that inverted-L & Inverted-F Antennas are formed. By doing this method, there is no need of quarter wave transformers.

The proposed structure has been simulated on FR4 epoxy glass substrate with dielectric constant (ε_r) of 4.4, loss tangent (tanδ) 0.02 and thickness (h) of substrate is 0.16cm. This structure is operated at a frequency of 2.4GHz for Bluetooth applications in portable devices such as mobiles, laptops, computers in building access points of WLANs and GPS terminals. Initially, patch antenna designed to resonate at one single frequency for Bluetooth application. To extend this antenna for various low frequency applications, slots are introduced for multiband applications. Figure 1 shows the iterative development of designed antenna. Geometries of designed antenna are shown in figure 2 and are listed in table 1.

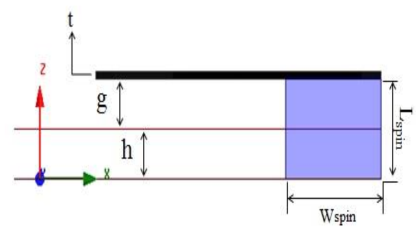


(a) First Iteration (b) Second iteration (c) Third iteration

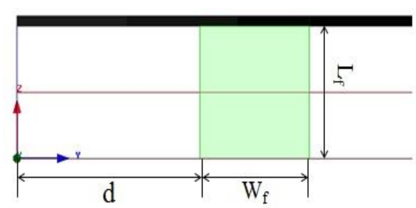
Fig.1: Iterative implementation of proposed antenna structure



(a) top view



(b) left view



(c) front view

Fig.2: Geometries of proposed antenna structure

Table 1: Parameters listed in figure (all units are in mm)

Ls	Ws	h	Lp	Wp	t	L1	L2	L3
58.94	35.9	1.6	39	15	0.25	35	30	20
W1	**W2**	**W3**	**L_{spin}**	**W_{spin}**	**L_f**	**W_f**	**G**	**D**
13	9	5.5	3.2	5	3.2	3	1.6	5

IV.RESULTS & ITS DISCUSSION

This complete antenna has been designed and simulated using High Frequency Structure Simulator (HFSS) software.

The electrical, far-field and current distribution characteristics are discussed below.

a) Electrical Characteristics:

Figure 3 shows the simulated return loss characteristics comparison of designed structure iterative implementations. Figure 4 shows the VSWR characteristics comparison.

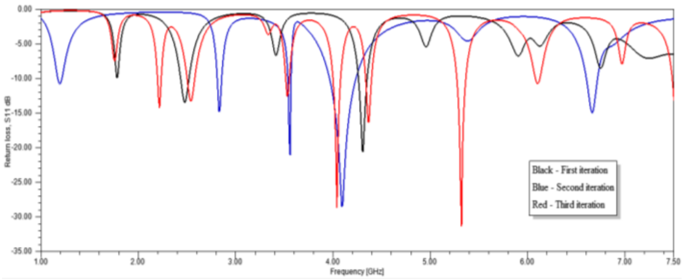


Fig.3: Return loss comparison of various iterative developments

From the observation of return loss characteristics in figure 3, the corresponding bandwidths are 2.44-2.52GHz=80MHz, 4.26-4.35GHz=90MHz with reflection coefficient's -13.52dB, -20.66dB at resonant frequencies 2.48GHz, 4.31GHz along with VSWR values are 1.53, 1.20 in figure 4 respectively for the first iteration structure. The responsive bandwidths of second iteration design are 2.23-2.26GHz=30MHz, 2.52-2.61GHz=90MHz, 4.02-4.09GHz=70MHz, 4.34-4.40GHz=60MHz, 5.31-5.39GHz=80MHz with -13.19dB, -14.22dB, -18.83dB, -14.27dB, -17.77dB at 2.25GHz, 2.56GHz, 4.05GHz, 4.37GHz, 5.35GHz respectively. Our designed structure is resonates at 2.22GHz, 2.54GHz, 4.04GHz, 4.37GHz, 5.32GHz with impedance bandwidths are 40MHz, 80MHz, 80MHz, 70MHz, 90MHz respectively.

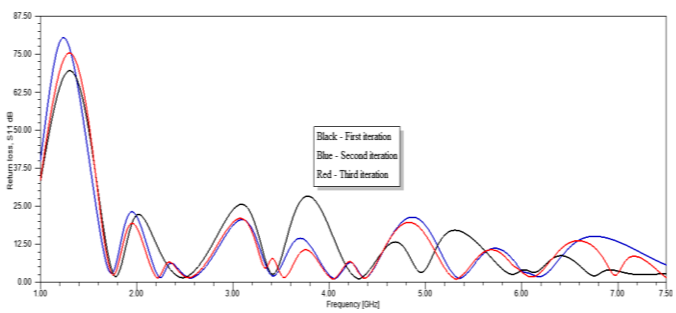
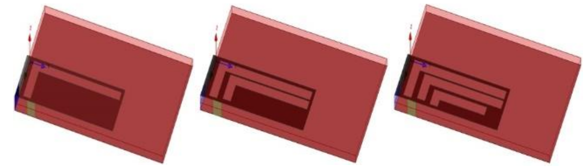


Fig.4: VSWR comparison of various iterative developments

In order to improve the narrow band antenna characteristics into broadband antenna characteristics, an air gap has been introduced in between the radiating patch and dielectric medium. One essential considering parameter in the antenna design is quality factor, which is directly proportional to the effective dielectric constant. By introducing an air gap, the effective dielectric constant decreases and proposed antenna works effectively. Figure 5 shows the modified proposed structure and length of air gap has been noted and mentioned in figure 2 and table 1.



(a) First Iteration (b) Second iteration (c) Third iteration

Fig.5: Modified proposed antenna designs

First iterative modified design produces dual band characteristics. Second iteration structure develops a quad band applicable antenna. Finally, proposed structure results penta band antenna at 1.20GHz, 2.82GHz, 3.58GHz, 4.02GHz and 6.68GHz frequencies. The simulated return loss characteristics are shown in figure 6. The corresponding impedance bandwidths are 1.16-1.25GHz=90MHz, 2.78-2.84GHz=60MHz, 3.55-3.60GHz=50GHz, 3.90-4.16GHz=260MHz and 6.60-6.79GHz=190MHz with reflection coefficients are -18.28dB, -17.29dB, -16.17dB, -27.97dB and -19.68dB respectively.

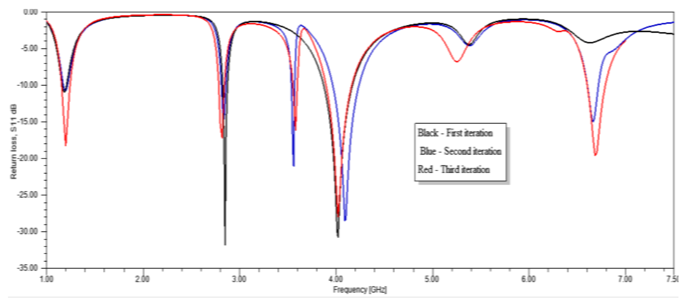
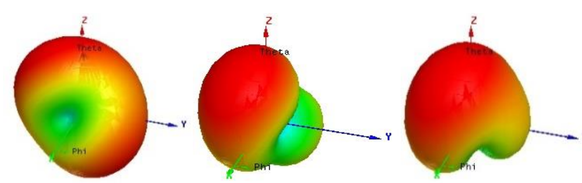


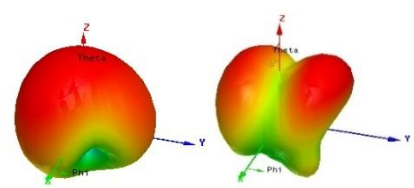
Fig.6: Various iterative comparisons of return loss characteristics

b) Far-field characteristics

Figure 7 shows the 3D gain plots of the proposed structure at their resonant frequencies. The maximum realized gains of the structure are 1.42dB, 1.43dB, 2.73dB, 2.43dB and 5.49dB respectively. Figure 8 shows the elevation and azimuthal planes of the designed antenna at different frequencies.

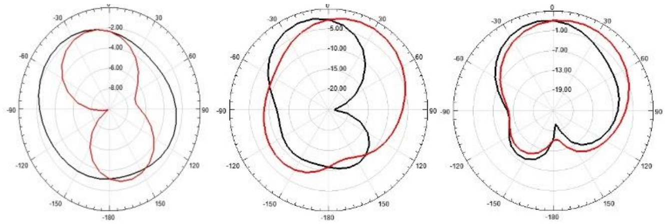


(a) 1.20GHz (b) 2.82GHz (c) 3.58GHz

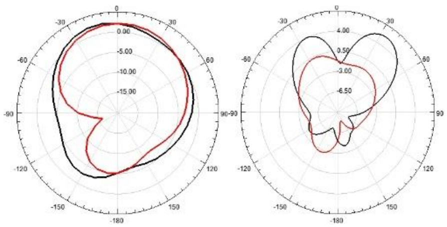


(d) 4.02GHz (e) 6.68GHz

Fig.7: 3D gain plots of the proposed antenna



(a) 1.20GHz (b) 2.82GHz (c) 3.58GHz

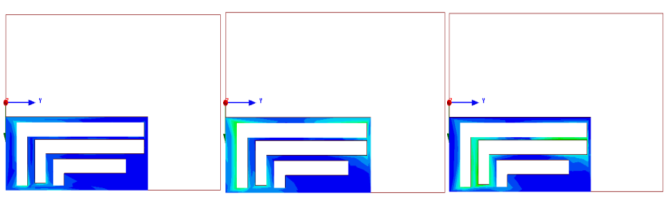


(d) 4.02GHz (e) 6.68GHz

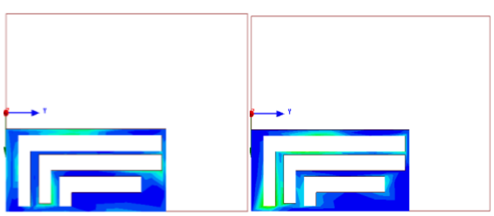
Fig.8: Radiation patterns of the proposed antenna (red – elevation & black - azimuth)

c) Surface Current distribution

Figure 9 shows the magnitude surface current distribution in the conducting element and figure 10 shows the vector surface current distributions at resonant frequencies.

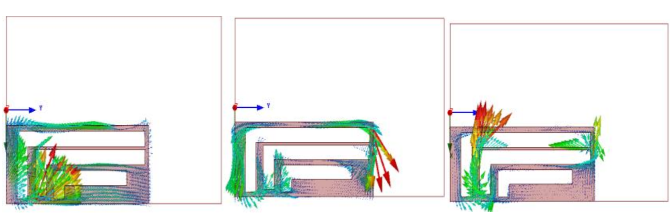


(a) 1.20GHz (b) 2.82GHz (c) 3.58GHz

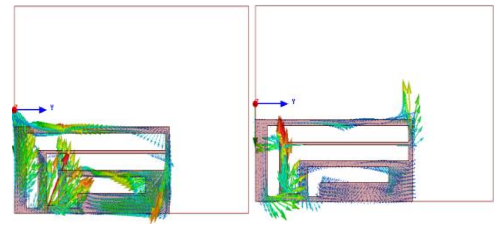


(d) 4.02GHz (e) 6.68GHz

Fig.9: Magnitude surface current distribution in proposed antenna



(a) 1.20GHz (b) 2.82GHz (c) 3.58GHz



(d) 4.02GHz (e) 6.68GHz

Fig.10: Vector surface current distribution in proposed antenna

d) Parametric analysis

The parameter ‘g’ is nothing but a height of an air gap between substrate and patch. From the observation of figure 11, the reflection coefficient values are inversely proportional with the parameter ‘g’ and also proportional with the resonant frequency. By varying the parameter ‘g’, we can control the resonant frequency to its corresponding application.

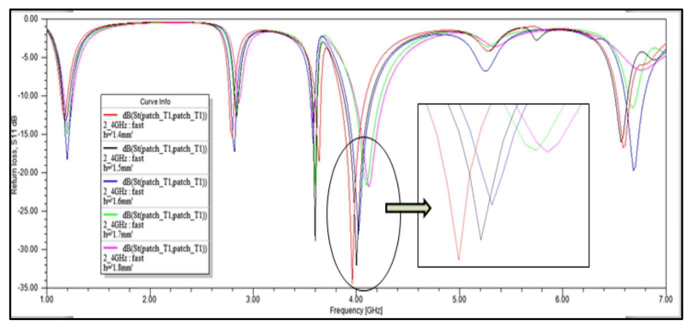


Fig.11: Return loss characteristics with respect to parameter ‘g’

V.CONCLUSION

In this paper, penta band L- shaped slotted Planar Inverted F-antenna has been designed and analyzed to cover low power wireless applications. The electrical, far-field and current distributions are simulated and plotted in this paper. The current distribution varies in accordingly with the size of slot. The main advantage of this antenna is only single antenna can cover multiple applications over L-, S- & C-bands.

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VII. REFERENCES

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